

EOS Multi-Mission Operations Concept for Phase 2

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Purpose & Scope

- ***Provide a preliminary Phase II end-to-end EOS multi-mission operations concept to be considered during Phase 1 design.***
 - *EOS series-1 spacecraft (AM-1, PM-1, LALT-1, CHEM-1)*
 - *Other MTPE spacecraft (LANDSAT-7, EO-1) considered in EPGS loading and operations concept*
 - *Operations period through 2003*
 - *Assumes AM-1 has transitioned to EPGS*
- ***Focus on spacecraft operations and science data acquisition***
 - *Science data processing operations not considered in detail*

EOS Series-1 Mission Profiles

Mission	Orbital Data Volume	Onboard Storage Capacity	Downlink Rates (bps)	Orbit Design Requirements	Mission Period
AM-1	110 Gbits	160 Gbits	150M (X-PB) 512K (S-PB) 16K (S-RT)	705 km circular 98.2 inclination 10:20 Descending Node	6/98 - 6/04
PM-1	52 Gbits	136 Gbits	150M (X-PB) 512K (S-PB) 16K (S-RT)	705 km circular 98.2 inclination 13:30 Ascending Node	12/00 - 12/06
LALT-1	7.5 Gbits/Day (compressed)	15 Gbits (TBD)	25M (X-PB) (TBD)	600 km circular 94.0 inclination No nodal requirement	7/01 - 7/06
CHEM-1	30.3 Gbits	88 Gbits	150M (X-PB) 512K (S-PB) 16K (S-RT)	705 km circular 98.2 inclination 13:45 Ascending Node	12/02 - 12/08
LANDSAT-7	Imaging: 378 Gbits every 42 min.	378 Gbits	150M (X-PB,RT) 256K (S-PB) 1 or 4K (S-RT)	705km circular 98.2 inclination 10:00 Descending Node	5/98- 5/05
EO-1	80 Gbits/Day	40 Gbits	105 Mbps (X-PB) 1 Mbps (S-PB)	705km circular 98.2 inclination 10:01 Descending Node	5/99 - 5/00

Note 1: 2kbps nominal S-band uplink rate for all spacecraft

Note 2: EPGS does not provide sole support for Landsat-7 or EO-1 missions (Reference Slide 11 for dump support details)

Operations Overview

■ ***Flight ops based on AM-1 concept***

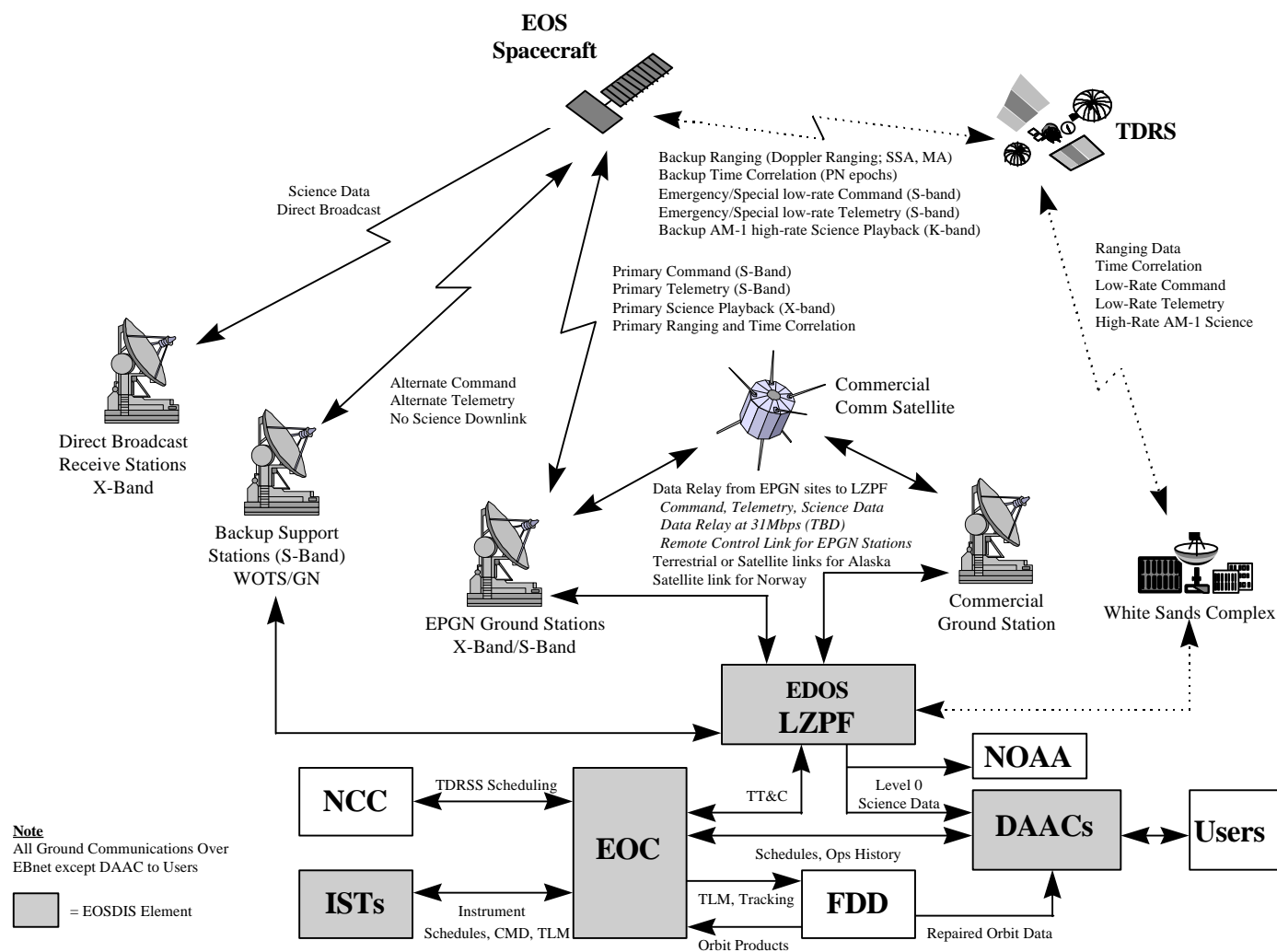
- *EOC is the focus of operations*
 - *Health & Safety monitoring for instruments & spacecraft*
 - *All mission planning, scheduling, and commanding*
 - *Ground System configuration & scheduling*
 - *Instrument Operations Teams (IOTs) provide instrument inputs via Instrument Support Toolkits (ISTs)*

■ ***Relatively autonomous spacecraft***

- *Automatic safing modes & reconfigurations*
- *Stored command loads*
- *Onboard ACS control loop*
- *Automated onboard data collection and storage*

■ ***Primary RF Link via EPGS***

EOS Ops Concept Overview



04/29/97

EOS Ground System (EGS) Overview

■ **Shared EGS Resources**

- *EOS Data & Operations System (EDOS)*
- *EOS Operations Center (EOC)*
- *EOSDIS Backbone Network (EBnet)*
- *EOS Polar Ground Stations (EPGS)*
- *NCC, TDRSS, FDD, SDVF (Institutional Resources)*
- *DAACs & Affiliated Data Centers (e.g., NOAA)*

■ **Flight-Specific Resources**

- *Flight-specific EOC databases, displays & tools*
- *Instrument-specific IST displays*
- *Spacecraft-specific simulators*

Communications Overview

■ ***EOS Polar Ground Stations (EPGS)***

- *Ground stations in Alaska & Norway*
- *Provide all primary communications with EOS spacecraft*
 - *S-band command & telemetry*
 - *X-band high rate downlink*
 - *Combined coverage = 15 min./orbit/spacecraft (average)*

■ ***WOTS provide backup S-band support***

■ ***TDRSS provides 70%+ orbital coverage:***

- *Special operations coverage (orbit maneuver burns, etc.)*
- *Emergency low rate command and telemetry*
- *Nominal tracking & clock correlation*
- *Backup high-rate K-band science downlink (AM-1 only)*

Daily Ground Station Coverage

*Typical for 705km circular orbit @98.2° inclination: Applies to AM-1, PM-1, CHEM-1
[LALT-1 coverage is approximately 10% less due to lower altitude orbit (600km)]*

	Norway	Alaska	Overlap	Gap	Total
Orbit 1	11:35	0	0	0	11:35
Orbit 2	11:42	0	0	0	11:42
Orbit 3	11:33	0	0	0	11:33
Orbit 4	11:29	0	0	0	11:29
Orbit 5	11:36	0	0	0	11:36
Orbit 6	11:42	8:40	0:35	0	19:47
Orbit 7	11:22	11:30	1:15	0	21:37
Orbit 8	10:19	11:16	1:40	0	19:55
Orbit 9	8:24	9:20	2:18	0	15:26
Orbit 10	5:56	7:19	3:50	0	9:25
Orbit 11	4:19	7:34	4:19	0	7:34
Orbit 12	5:36	9:43	2:02	0	13:17
Orbit 13	8:05	11:26	1:05	0	18:26
Orbit 14	10:07	11:17	0:27	0	20:57
Orbit 15	11:17	7:40	0:00	0:39	18:57
Total	145:02	95:45	17:31		223:26
Average	9:40	9:34			14:53

Assumptions: 5° minimum elevation and line-of-sight links (no spacecraft masking).

Total coverage per orbit adds coverage times for Alaska and Norway and subtracts any overlap.

Orbits with no Alaska coverage not included in Alaska average calculation. Alaska average for all orbits is 6:23.

Onboard Data Management

■ ***Solid State Recorder (SSR) Assumptions for EOS Series-1 Spacecraft***

- *At least 2-orbit capacity except for AM-1 (see table on next page)*
- *Partitioned for each instrument & spacecraft H/K*
- *Multiple Inputs, single output*
- *Simultaneous record/playback (including H/K except on AM-1)*
- *Data Position Pointers in X-band & S-band downlinks*
- *Write-protectable data*
- *Playback order managed by the Flight Operations Team*

Data Volumes & Downlink Times

(X-band dump time per orbit)

	Data Volume (per orbit)	Downlink Rate	Downlink Time/Orbit	Recommended Dump Plan
AM-1	110 Gbits	150 Mbps	12:13	Every Contact (1-2/orbit)
PM-1	52 Gbits	150 Mbps	5:47	Once per Orbit
LALT-1	0.5 Gbits	25 Mbps	0:20	Once per Day ³
CHEM-1	30.3 Gbits	150 Mbps	3:22	Once per Orbit
LANDSAT-7	324 Gbits ¹	150 Mbps	36:00	See Note 2
EO-1	5.33 Gbits	105 Mbps	00:51	4 Dumps/Day ³

Note 1: LANDSAT-7 data volume equals 36 minutes of imaging (42 minute recorder capacity)

Note 2: EPGS sites not prime for all LANDSAT-7 support. 4 passes per day requested for AGS, 1 pass for SGS..

Note 3: Dump plan requires greater than 2-orbit recorder capacity.

Note 4: EPGS now prime for EO-1 support. 4 passes per day requested..

EPGS Contact Scenario

■ **Primary Ground Station**

- *S-band Telemetry*
 - *Real-time housekeeping data for duration of pass*
 - *Capability to dump playback housekeeping data*
- *Real-time S-band commands and command load uplinks*
- *X-band Dump*
 - *Playback housekeeping data followed by science data*

■ **Secondary Ground Station** *(on same orbit - if any)*

- *Extended S-band real-time telemetry if schedule allows*
- *Additional X-band playback time (if required)*

■ **Ground Station Control**

- *Ground station status monitored by the EOC during the pass*
- *Pre-pass interface checks performed by the EOC*

EGS Data Routing

■ ***EPGS Ground Stations***

- *Acquire S-BD and X-BD downlinks*
- *Throughput S-BD downlinks to LZPF in real-time*
- *Forward X-BD dump data to LZPF post-pass*

■ ***Real-Time S-band Telemetry***

- *Forwarded from EPGS to EOC in real-time*
 - *EPGS to LZPF*
 - *via satellite link from Norway (rate TBD)*
 - *via satellite or ground link from Alaska (rate TBD)*
 - *LZPF performs level zero processing*
 - *LZPF forwards data to EOC*

EGS Data Routing (continued)

■ ***X-band dumps***

- *Recorded at the ground station during the pass*
- *Forwarded from EPGS site to LZPF post-pass*
 - *Via ground or satellite link (rate TBD)*
 - *Data forwarded in priority order*
 - *Housekeeping (supports health & safety analysis prior to next orbit)*
 - *Instrument science data in priority order*
 - *Order of forwarding determined by order of S/C playbacks*
- *LZPF forwards data to appropriate destination*
 - *VCID and APID processing*
 - *Housekeeping data to EOC (also to ASTER ICC for AM-1)*
 - *Level zero processed science data sets to appropriate DAAC*

Science Data Quality Monitoring

- *Phase 1 data quality monitoring is limited to EPGS sites (due to tape shipment of data)*
- *Phase 2 data quality monitoring can be performed at EPGS sites and/or EDOS LZPF (due to timely data transfers)*
- *Troubleshooting of poor quality science data is coordinated by the EOC*

Ground Station Scheduling

- *EOC determines ground station support schedule requirements for all EOS spacecraft.*
 - *Determined mainly by spacecraft orbit and coverage times*
 - *Also affected by data volumes, command activity, recorder capacity, data rates, and real-time monitoring requirements.*
- *EOC generates integrated EPGS schedule request for all EOS spacecraft*
- *EPGS scheduling process TBD*

Commanding Operations

- *All commanding performed by EOC*
- *S-band Command links available to each spacecraft each orbit via EPGS*
- *CCSDS Command Operations Procedure 1*
- *Real-time commanding for dump control and anomaly resolution*
- *Time-tagged command load uplinks for most nominal mission operations*
- *Command routing: FOS to EDOS to EPGS*

Health & Safety Monitoring

■ ***Performed by EOC for spacecraft and all instruments***

- *Instruments may also be monitored via IST or Instrument Control Centers by Instrument Operations Teams (IOTs)*

■ ***Housekeeping Data***

- *Processed at EOC (real-time and playback data)*
- *Playback data forwarded to EOC within 30 minutes of contact*

■ ***Housekeeping Playbacks***

- *Nominally dumped via X-band*
- *S-band dump also available, but reduces time for X-band science dump*

Flight Dynamics Support

■ ***Tracking data***

- *TDRSS tracking planned for AM-1(TONS), PM-1*
- *Use of EPGS tracking data to be analyzed by FDD*
- *Tracking by non-EPGS ground sites may also be available*
- *LALT-1 GPS may eliminate most tracking support needs*
- *Tracking data processed on FDD systems*

■ ***Clock correlation via EPGS***

- *TDRS PN Epoch method planned for AM-1, PM-1*
- *EPGS clock correlation alternatives to be analyzed*

■ ***FDD System at EOC generates all routine products:***

- *Planning aids, daily predicted orbit updates, acquisition data*

Ground Station Contention (?)

- *EPGS sites can support multiple missions*
- *EPGS loading analysis for Phase 2 in work (D. Elwell)*
- *EOS series-1 constellation design mandatory prior to PM-1 launch*
 - *Coordinated orbit design/maintenance alleviates ground station contention*

EPGS to LZPF Bandwidth Contention (?)

- ***Data downlink per orbit period for all EOS series-1 spacecraft is 199.8 Gbits (maximum)***
 - *Equates to 74-minute transmission time @ 45Mbps (T3)*
 - *Based on a 100 minute EOS orbit period, 45Mbps EBnet bandwidth supports Phase 2 EOS mission requirements for timely data recovery*
 - *74-minute transmission time assumes that all data goes to a single ground site and is transmitted over a single T3 line (worst case)*
- *Good constellation design is required to eliminate transmission delays*
- *If full T3 capacity is not available, there may be problems as transmission time approaches 100 minutes on single-site orbits*

Spacecraft Implications

- *Multi-mission operations concept impacts spacecraft design requirements, e.g.*
 - *Onboard recorder sizing*
 - *Downlink rates & formats*
 - *Spacecraft autonomy*
 - *Tracking systems*
- *EOS MOM coordinating with flight projects to ensure spacecraft designs are consistent with multi-mission operations concept*

Next Steps

- ***Determine science data quality monitoring implementation***
- ***Determine EPGS scheduling process***
 - *for EOS spacecraft*
 - *for non-EOS spacecraft (Landsat, etc.)*
- ***Perform EOS series-1 constellation design***
- ***Plan working meeting to generate EPGS multi-mission operations concept to support June 1997 EPGS Phase 2 architecture review***

Acronym & Abbreviation List

ACS	Attitude Control System	GSIF	Ground Station Interface Facility
AI	Artificial Intelligence	H/K	Housekeeping
AIRS	Atmospheric Infrared Sounder	HSB	Humidity Sounder Brazil
AM	EOS AM Mission	ID	Identifier or Identification
AMSR	Advanced Microwave Scanning Radiometer	IOT	Instrument Operations Team
AMSU	Advanced Microwave Sounding Unit	IST	Instrument Support Toolkit
ASAP	As Soon As Possible	KBPS	Kilobits Per Second
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer	KM	Kilometer
BAP	Baseline Activity Profile	LALT	EOS Laser Altimeter Mission
BD	Band	LEO	Low Earth Orbit
CAC	Command Activity Controller	LZPF	Level Zero Processing Facility
CCSDS	Consultative Committee for Space Data Standards	MA	Multiple Access
CERES	Clouds & Earth's Radiant Energy System	MBPS	Megabits Per Second
CHEM	EOS Chemistry Mission	MGA	Medium Gain Antenna
CMD	Command	MIN	Minutes
CMS	Command Management System	MODIS	Moderate Resolution Imaging Spectrometer
CRC	Cyclic Redundancy Check	NCC	Network Control Center
DAAC	Distributed Active Archive Center	NOAA	National Oceanic & Atmospheric Administration
EBNET	EOSDIS Backbone Network	PM	EOS PM Mission
EDOS	EOS Data and Operations System	PN	Pseudo-Random Noise
EGS	EOS Ground System	RF	Radio Frequency
EOC	EOS Operations Center	RTCS	Relative Time Command Sequence
EOS	Earth Observing System	RTN	Return
EOSDIS	EOS Data and Information System	SDVF	Software Development & Verification Facility
EPGS	EOS Polar Ground Stations	SSA	S-band Single Access
FDD	Flight Dynamics Division	SSR	Solid State Recorder
FDIR	Failure Detection, Isolation, Recovery	TBD	To Be Determined
FOS	Flight Operations System	TDRS	Tracking & Data Relay Satellite
FOT	Flight Operations Team	TDRSS	Tracking & Data Relay Satellite System
FS	Slight Software	TLM	Telemetry
FWD	Forward	TMON	Telemetry Monitor
Gbit	Gigabit	TOO	Targets Of Opportunity
		WOTS	Wallops Orbital Tracking Station